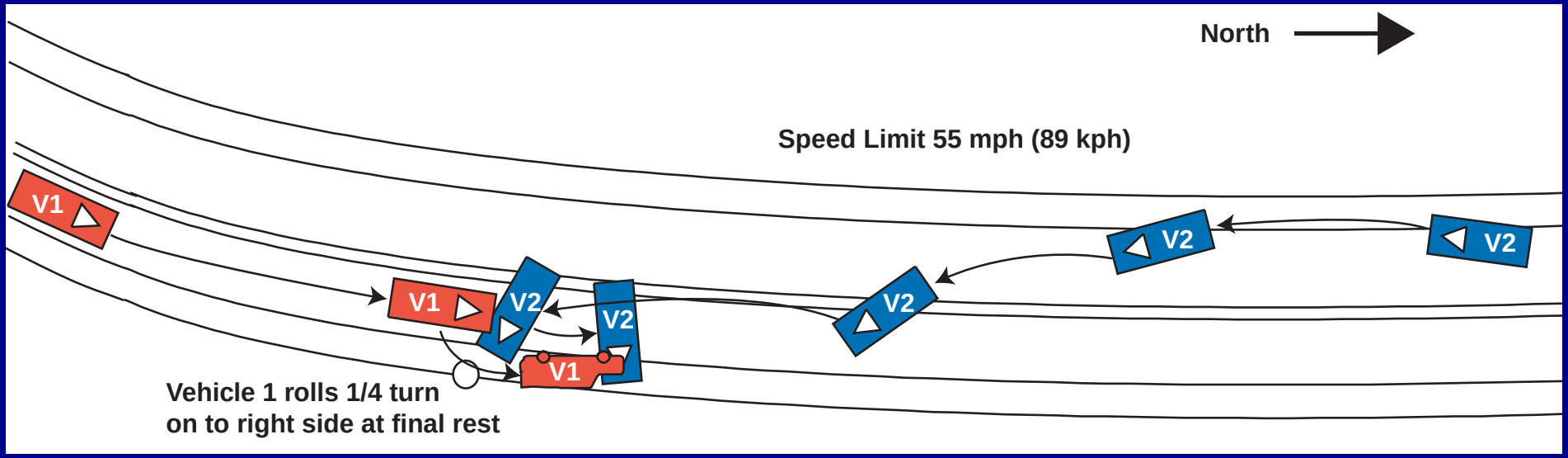
# A Diagnostic Challenge:

# Cervical Spine Injuries in Children

**University of Michigan**

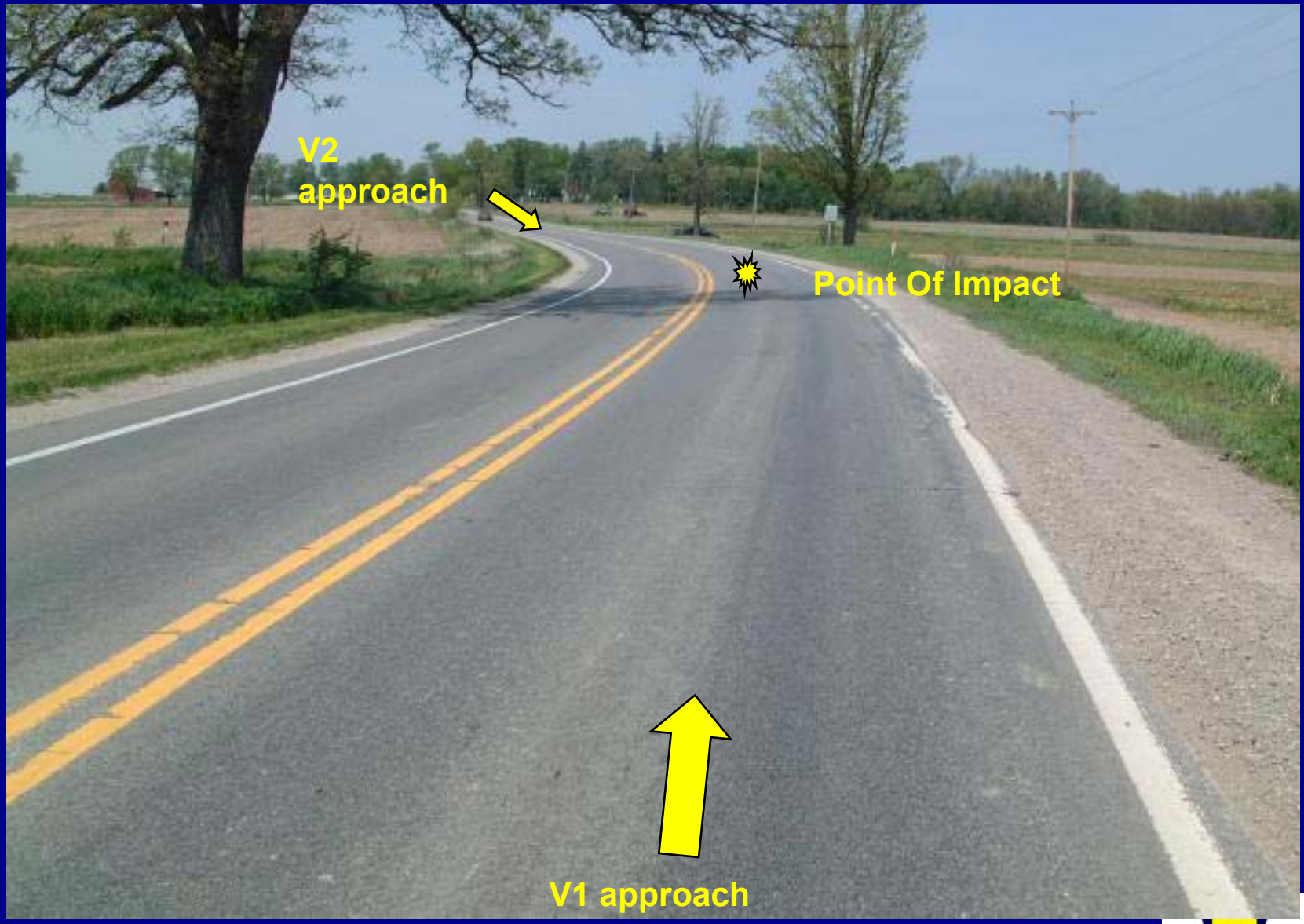
**Program for Injury Research and Education**

# Crash Scenario




- 1994 Ford Explorer, 4 x 4, SUV vs 1995 Ford Assembled vehicle (1993 Ford Probe body)
- Daylight, rain, wet asphalt roadway
- Driver of V2 lost control of vehicle, entered a Counter Clockwise (CCW) yaw, crossed centerline and into path of V1
- Front of V1 struck the right-side of V2 in a T-type configuration
- V2 rapidly rotates CCW around V2 causing secondary side-slap
- V1 rolls on quarter turn onto right side
- Four occupants of V1
- Driver is lone occupant of V2, partially ejected, fatally injured

# Crash Scene
## Roadway Overview



# Case Vehicle - 1994 Ford Explorer

Case vehicle as found in the tow yard - representative of FRP

# Case Vehicle - 1994 Ford Explorer

# Case Vehicle - 1994 Ford Explorer

Impact #1

| | |
|---|---|
| **CDC :** | **12-FDEW-3** |
| **Direct damage length:** | **157 cm** |
| **Max Crush:** | **49 cm** |
| **PDOF:** | **350 degrees** |
| **Severity:** | **28 mph ΔV** |
| | **- 28 longitudinal** |
| | **5 lateral** |

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# Case Vehicle - 1994 Ford Explorer

Impact #2

| | |
|---|---|
| **CDCs :** | **09-LYAW-3** |
| **Direct damage length:** | **214 cm** |
| **Max Crush:** | **10 cm** |
| **PDOF:** | **270 degrees** |
| **Severity:** | **6 mph ΔV** |
| | **0 longitudinal** |
| | **+6 lateral** |

# Case Vehicle - 1994 Ford Explorer

Impact #3

| | |
|---|---|
| **CDCs :** | **00-RDA0-2** |
| **Direct damage length:** | **409 cm** |
| **Max Crush:** | **less than 1 cm** |
| **PDOF:** | **non-horizontal** |
| **Severity:** | **minor** |

# Vehicle 2 - 1993-95 Ford Probe

Impact #1

| | |
|---|---|
| **CDC :** | **12-RDAW-5** |
| **Direct damage length:** | **310 cm** |
| **Max Crush:** | **98 cm** |
| **PDOF:** | **70 degrees** |
| **Severity:** | **40 mph ΔV** |
| | **-14 longitudinal** |
| | **- 38 lateral** |

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# Case Vehicle - 1994 Ford Explorer

Driver

Non-case occupant

**37-year-old female**

**5 ft 2 in tall**

**110 lb**

**3-point manual belt worn**

**contusion mid forehead, contusion around right eye, and contusion left forearm, bloody nose**

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# Case Occupant A

- left rear
- 3-year-old male
- 3 ft 3 in tall
- 33 lb
- 3-point manual belt worn with shoulder belt behind back
- No intrusions

# Left Rear - 1994 Ford Explorer


# Left Rear - 1994 Ford Explorer

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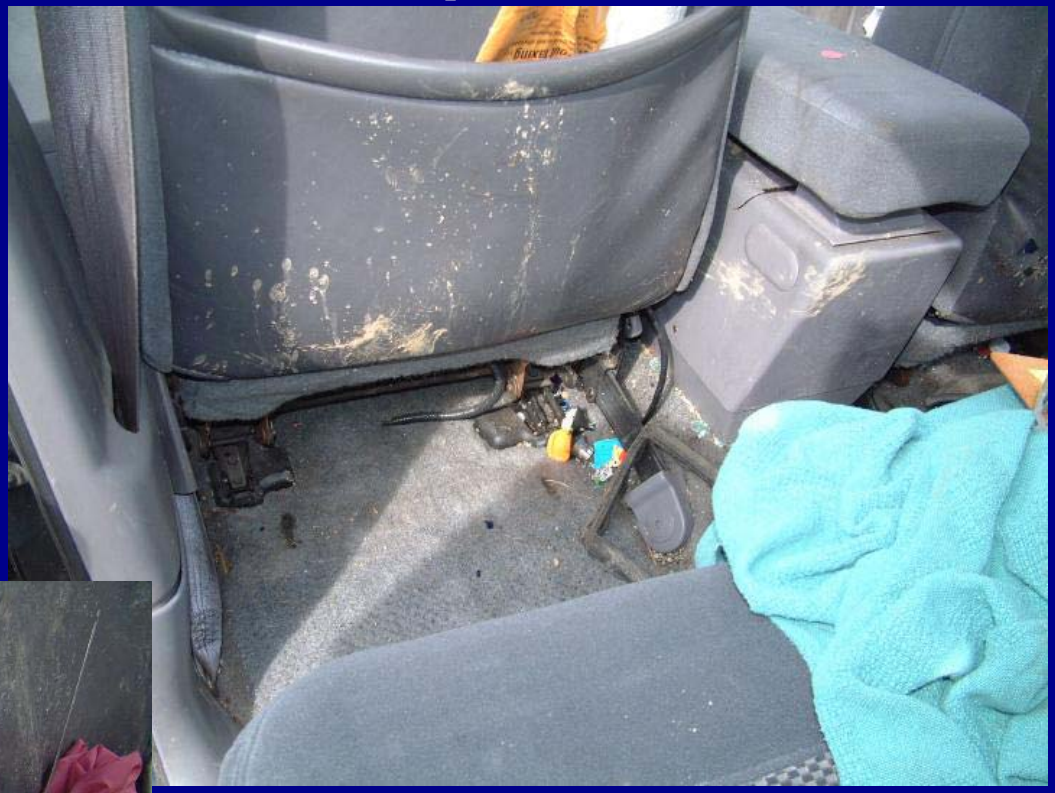
# Left Rear - 1994 Ford Explorer



# Case Occupant B

- right rear
- 6-year-old male
- 4 ft tall
- 50 lb
- 3-point manual belt worn with shoulder belt behind back
- No intrusions

# Right Rear - 1994 Ford Explorer

# Right Rear - 1994 Ford Explorer

# Right Rear - 1994 Ford Explorer

# Case Occupant C

- Right front
- 7-year-old female
- 4 ft 1 in tall
- 75 lb
- 3-point manual belt worn
- Intrusions
  - Toe pan 9 cm to rear
  - Floor pan 11 cm up

# Right Front - 1994 Ford Explorer





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# Right Front - 1994 Ford Explorer

# Occult Injuries
## Worst case scenario

- Injury not clinically apparent by exam.
- Patient unable to communicate.
- Injury difficult to diagnose.
  - Anatomic variation due to developmental changes or senescence.
  - Technically difficult to image.
- Severe (*potentially preventable*) consequences.

# Medical Summary

A: Left rear

B: Right rear

C: Right front

# Case Occupant A

- Left rear
- 3-year-old male
- 100 cm (3’ 3”)
- 15 kg (33 lb)
- 3-point manual belt worn with shoulder belt behind back

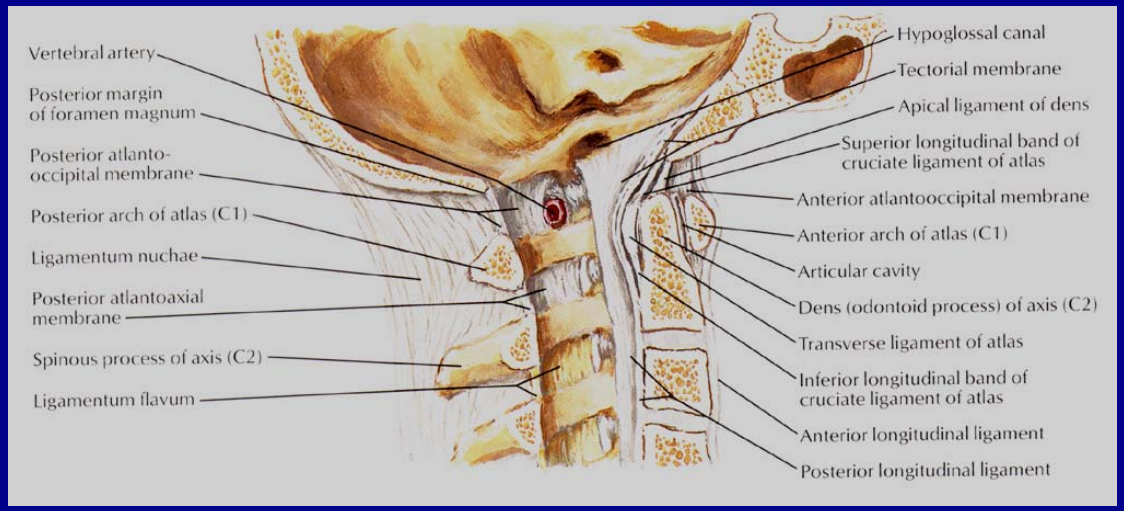
# A:  3 year old Left Rear Passenger

# A: 3 year old Left Rear Passenger

# A: 3 year old Left Rear Passenger

| Injury | AIS | Contact Area |
|---|---|---|
| Small bowel perforation | 3 | Lap belt |
| Mesenteric hematoma | 2 | Lap belt |
| Bilateral iliac wing fractures | 2, 2 | Lap belt |
| | | |

# A: 3 year old Left Rear Passenger

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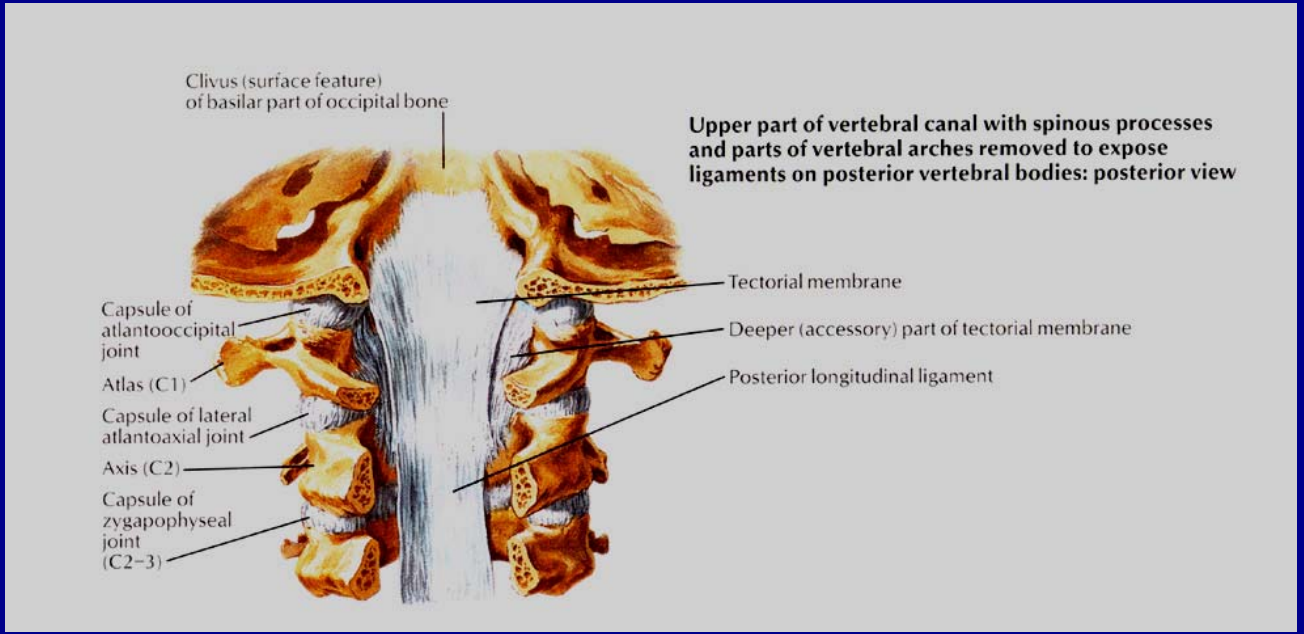
# A: 3 year old Left Rear Passenger

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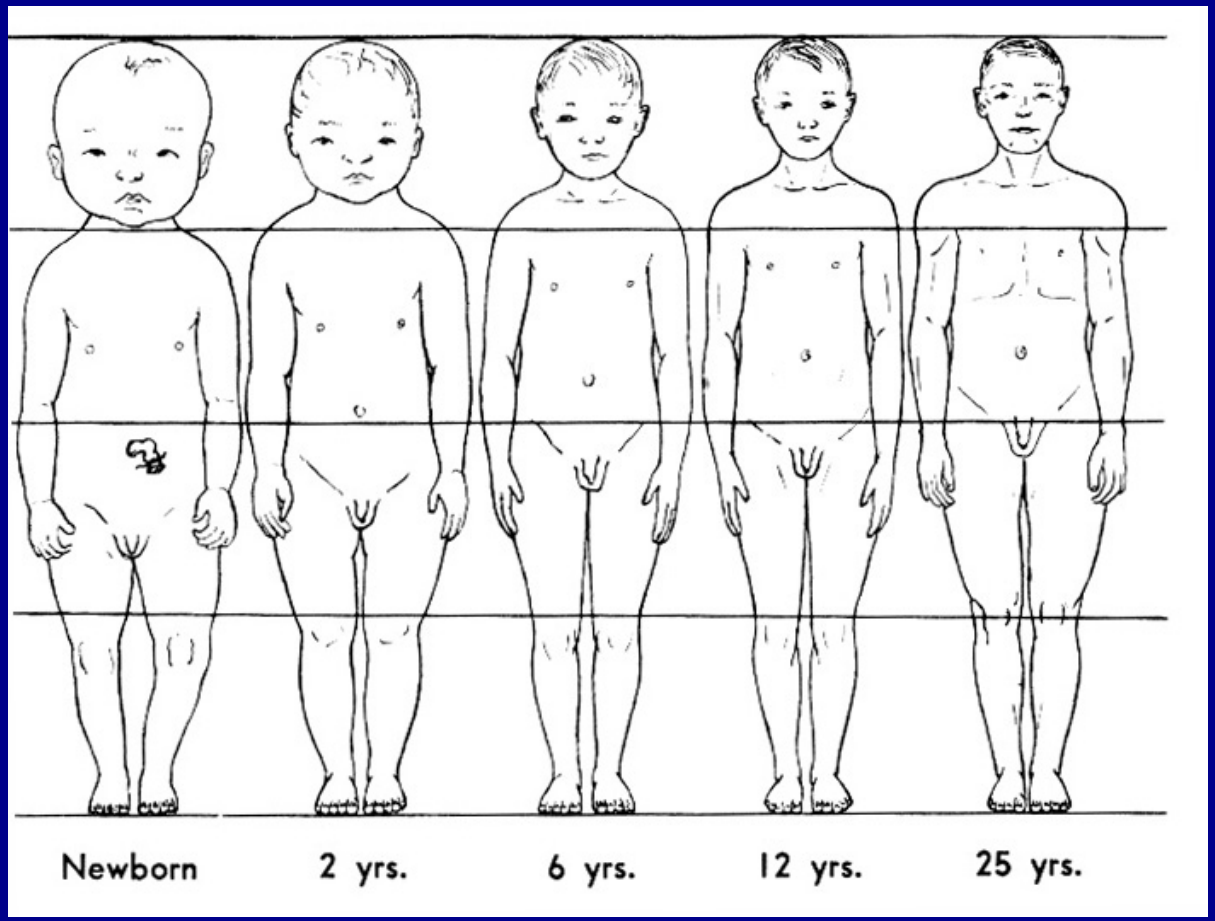
# Child ≠ Small Adult

We all know that early childhood is a time of rapid changes. From the crash perspective, it is critical to keep in mind that children are not scaled down versions of adults. For instance, in the following slide, one can see that the head is proportionately much larger in the infant and young child. Normal body proportions are not reached until approximately 10 years of age.

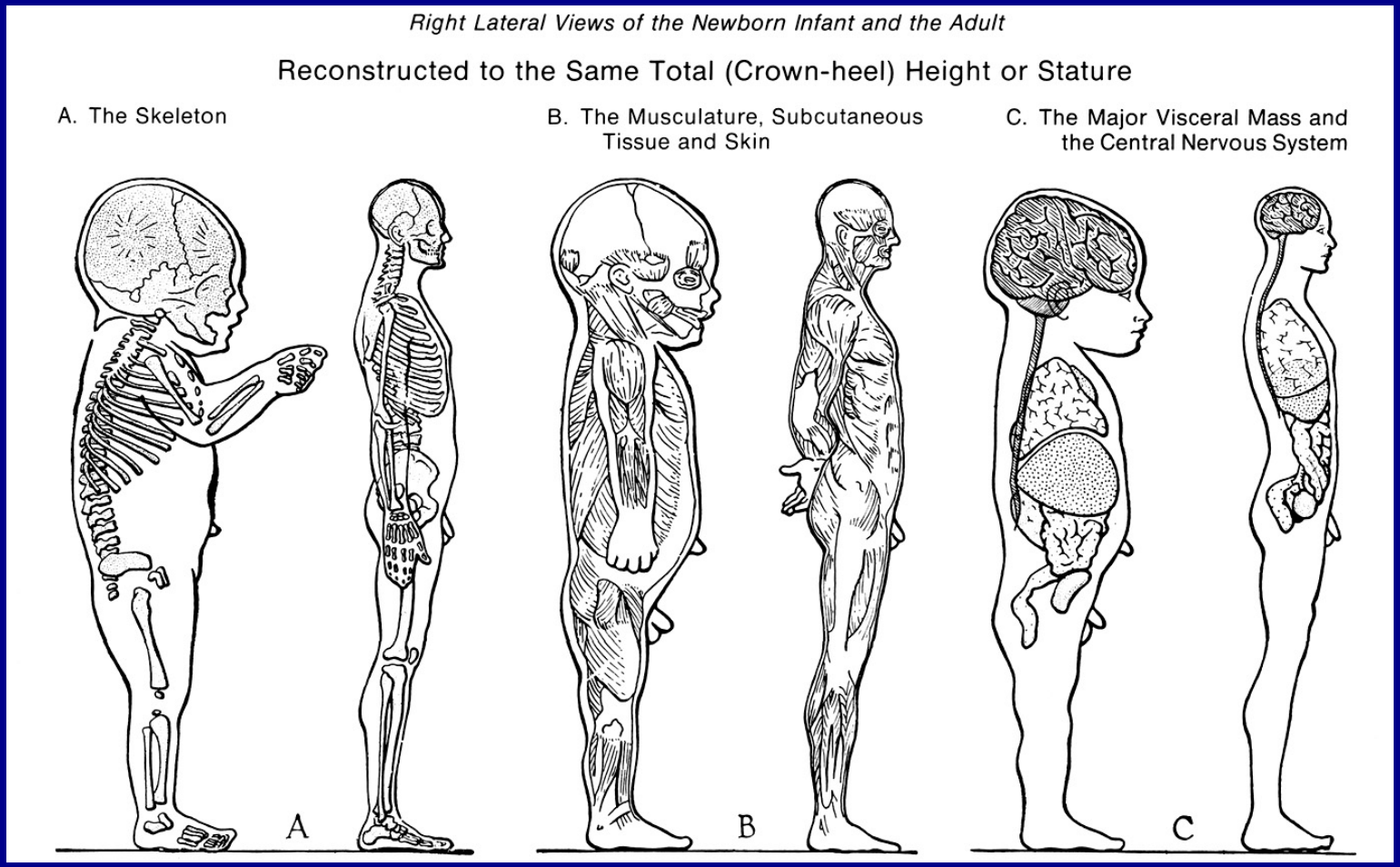
# Child ≠ Small Adult



# A Child's Neck is Under-developed

This problem is worsened from the crash injury standpoint by the fact that an under-developed neck supports an oversized head. As shown in the following slide, the vertebrae of the neck are much weaker than in the adult, often containing cartilage that has not hardened into bone. The muscles of the neck are weak and under-developed, you see this yourself with young infants who can't hold up their heads. The ligaments binding the vertebrae together are also loose to accommodate growth. In a crash, a large amount of stress is placed on the under-developed neck and injuries can result.

# A Child's Neck is Under-developed



# A: 3 year old Left Rear Passenger

| Injury | AIS | Contact Area |
|---|---|---|
| Small bowel perforation | 3 | Lap belt |
| Mesenteric hematoma | 2 | Lap belt |
| Bilateral iliac wing fractures | 2, 2 | Lap belt |
| **A-O dissociation** | **2** | **Non-contact** |

# Case Occupant B

- Right rear
- 6-year-old male
- 122 cm (4’)
- 23 kg (50 lb)
- 3-point manual belt worn with shoulder belt behind back

# B:  6 year old Right Rear Passenger

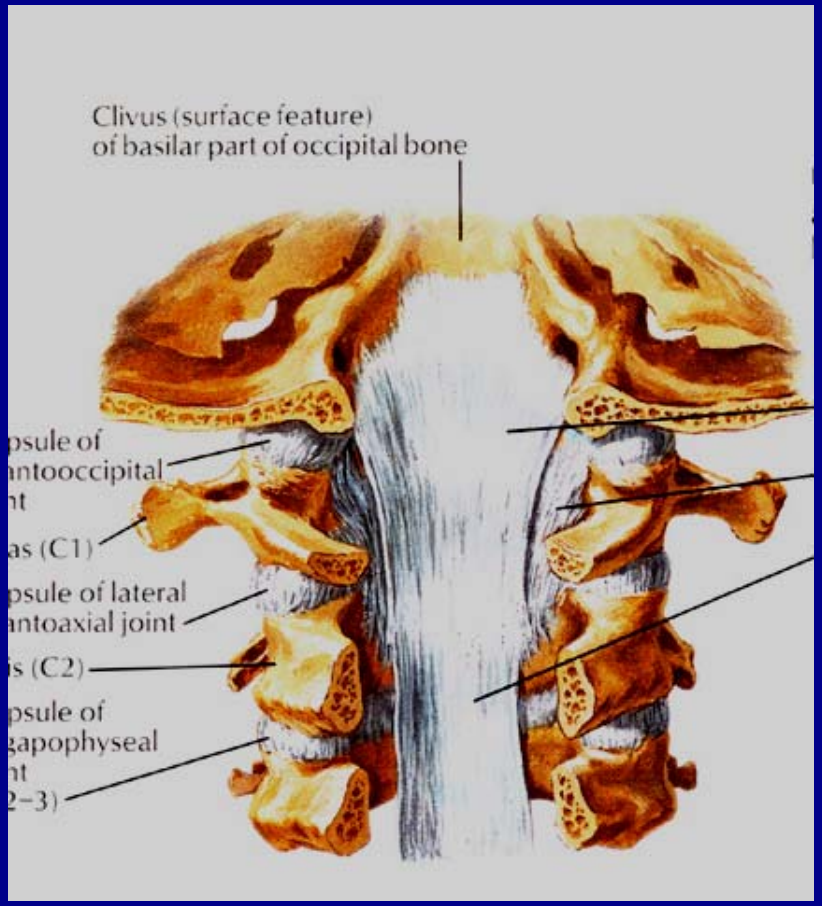
# B: 6 year old Right Rear Passenger

# B: 6 year old Right Rear Passenger

# B: 6 year old Right Rear Passenger

| Injury | AIS | Contact Area |
|---|---|---|
| Small bowel devascularization x 2 | 4 | Lap belt |
| Right frontal bone fracture | 3 | Right front seat back frame |
| Right frontal lobe contusion | 3 | Right front seat back frame |
| Right subarachnoid hemorrhage | 3 | Right front seat back frame |
| Colon perforation | 3 | Lap belt |
| L2-3 spinous process avulsion fractures | 2, 2 | Flexion around lap belt |
| L4 vertebral body fracture | 2 | Flexion around lap belt |
| | | |

# B: 6 year old Right Rear Passenger

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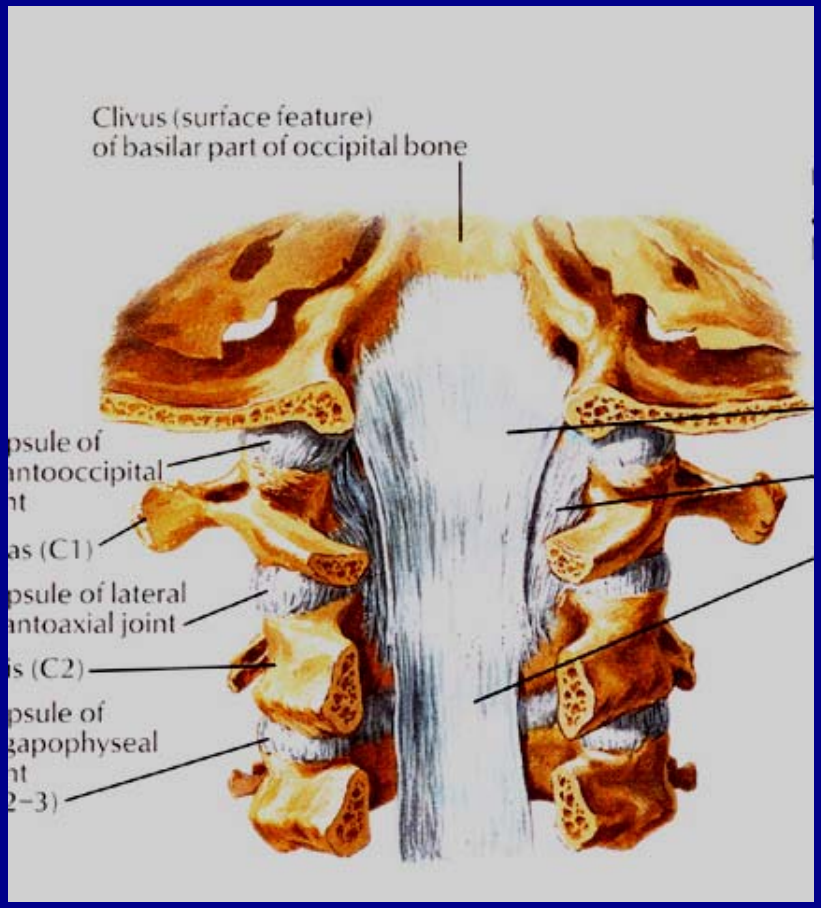
# B: 6 year old Right Rear Passenger

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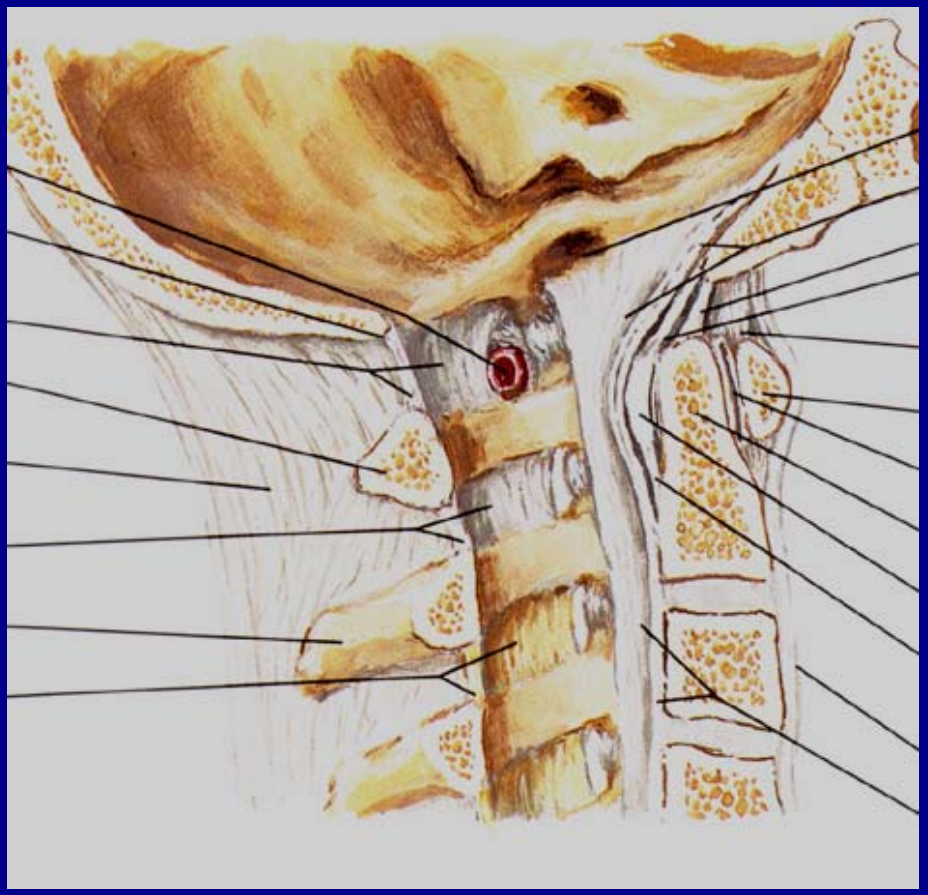
# B: 6 year old Right Rear Passenger



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# B: 6 year old Right Rear Passenger

| Injury | AIS | Contact Area |
|---|---|---|
| Small bowel devascularization x 2 | 4 | Lap belt |
| Right frontal bone fracture | 3 | Right front seat back frame |
| Right frontal lobe contusion | 3 | Right front seat back frame |
| Right subarachnoid hemorrhage | 3 | Right front seat back frame |
| Colon perforation | 3 | Lap belt |
| L2-3 spinous process avulsion fractures | 2, 2 | Flexion around lap belt |
| L4 vertebral body fracture | 2 | Flexion around lap belt |
| **A-O dissociation** | **2** | **Non-contact** |

# Case Occupant C

- Right front
- 7-year-old female
- 124 cm (4’ 1”)
- 35 kg (75 lb)
- 3-point manual belt worn

# C: 7 year old Right Front Passenger

floor pan = 11 cm upward

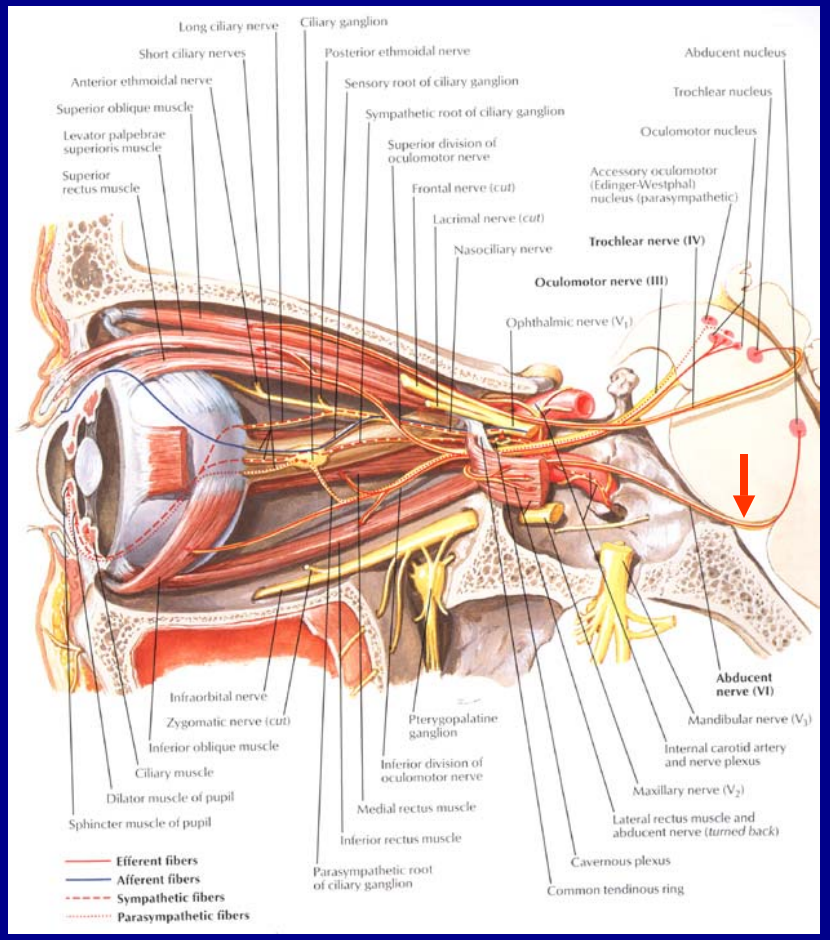
toepan = 9 cm rearward

# C: 7 year old Right Front Passenger

# C: 7 year old Right Front Passenger

| Injury | AIS | Contact Area |
|---|---|---|
| Bilateral pulmonary contusions | 4 | Shoulder belt |
| Left #2-6 anterior-lateral rib fractures | 3 | Shoulder belt |
| | | |

# C: 7 year old Right Front Passenger

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# C: 7 year old Right Front Passenger

| Injury | AIS | Contact Area |
|---|---|---|
| Bilateral pulmonary contusions | 4 | Shoulder belt |
| Left #2-6 anterior-lateral rib fractures | 3 | Shoulder belt |
| A-O dissociation | 2 | Non-contact |

# Summary

- Pediatric cervical spine injuries
  - Are often occult.
  - Can be difficult to diagnose.
- These cases
  - Illustrate the age dependence of injury tolerance.
  - No spinal cord injury – VERY unusual.
  - At threshold of neck injury tolerance.
  - Good documentation, multi-modal 3D data …..modeling?

# MADYMO Model : Assessment of Occupant Kinematics

- **MADYMO model** based on actual vehicle
- **Vehicle Environment (internal geometry)** obtained from previous simulations
- **Crash Pulse** obtained from NHTSA FMVSS 208 compliance test (30mph)
- **Occupants simulated** using Hybrid III 6 year old models for right rear and right front, Hybrid III 3 year old model for left rear
- **Finite Element Seat Belts** created to emulate reported belt conditions for 3 children in vehicle

# Model Assumptions

- **Seat Belt Mounting Points** based on actual vehicle
- **Seat, Belt, Contact properties** obtained from other models
- **Belt Usage** as reported in CIREN case file (shoulder belt behind back of rear passengers)
- **Crash Pulse** applied at 12:00
- **Passengers Seated** normally, legs together, facing forward, upright except right rear, for which other positions were investigated
- **Belt Slack and Seating** conditions for right rear occupant varied to investigate head contact

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# Comparison of Case Occupants to Dummy Models

| | Age | Height | Weight |
|---|---|---|---|
| Vehicle Occupants | 3 years | 100 cm | 15 kg |
| | 6 years | 122 cm | 23 kg |
| | 7 years | 124 cm | 35 kg |
| Hybrid3 Dummies | 3 years | 94.5 cm | 15 kg |
| | 6 years | 114 cm | 23 kg |

# Neck Injury (Hybrid III ATDs)